

Surface Distress Index-Based Pavement Condition Assessment Using Visual Survey Method: A Case Study of Flexible Pavement on Deandels Road, East Java, Indonesia

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ABSTRACT

Road infrastructure deterioration is a critical challenge for regional road authorities in Indonesia. This study applies the Surface Distress Index (SDI) method through a systematic visual survey to assess the structural pavement condition of a 4,500-meter section of Deandels Road in Probolinggo Regency, East Java, covering 45 segments of 100 meters each. SDI scores were computed by evaluating crack area, crack width, pothole count, and rutting depth per segment. Results show that 66.7% of segments are in good condition (SDI < 50), 8.9% Fair, 22.2% Light Damage, and 2.2% Severe Damage. The most critical failure was identified at STA 2+900-3+000 (SDI = 155), requiring full reconstruction. A maintenance priority framework yields a total estimated cost of IDR 937,284,642.47. The SDI method proved effective as a practical, low-cost tool for pavement management in resource-constrained regional road authorities

INTRODUCTION

Road infrastructure constitutes a fundamental component of land transportation systems, exerting a significant influence on regional mobility, economic logistics, and social connectivity. The quality of road surfaces directly affects the safety and comfort of road users, as well as the operational cost of vehicles. Pavement deterioration, when left unaddressed, follows a progressive trajectory in which minor surface distress evolves into structural failures, ultimately requiring costly reconstruction rather than preventive maintenance.

In Indonesia, many regional roads experience accelerated deterioration due to high traffic loading, particularly from overloaded heavy vehicles, combined with inadequate drainage systems and suboptimal construction quality. This situation places considerable pressure on local governments, which often operate under constrained maintenance budgets. Effective pavement management therefore requires objective, systematic, and cost-efficient methods for assessing road conditions and prioritizing maintenance interventions.

The Surface Distress Index (SDI) is a standardized visual assessment method adopted as the standard road condition survey instrument in Indonesia under the guidelines of the Directorate General of Highways (Direktorat Jenderal Bina Marga). The SDI quantifies pavement condition by scoring four key distress parameters: crack area percentage, crack width, number of potholes per 100 m, and rutting depth. The cumulative score classifies each road segment into one of four condition categories - Good, Fair, Light Damage, and Severe Damage - each corresponding to a specific maintenance treatment strategy.

Deandels Road in Probolinggo Regency, East Java, is a critical regional corridor connecting urban and peri-urban areas. The road experiences substantial daily traffic, including heavy freight vehicles, making it susceptible to structural pavement failure. Preliminary observations indicated multiple forms of surface distress including cracking, potholing, and rutting. However, no systematic quantitative assessment of its structural condition had previously been conducted to guide maintenance planning.

This study aims to: (1) quantify the pavement condition of Deandels Road using the SDI method across all 45 segments of a 4,500-meter section; (2) identify the spatial distribution and critical concentration of distress; and (3) formulate a maintenance priority framework and cost estimation based on SDI classification outcomes. The results are intended to support evidence-based decision-making by the Public Works Office (Dinas Pekerjaan Umum) of Probolinggo Regency.

LITERATURE REVIEW

Surface Distress Index (SDI)

Flexible pavement, or asphalt concrete pavement, is designed to distribute traffic loads through multiple bound and unbound layers to the subgrade. Common distress types include alligator cracking (fatigue failure), longitudinal and transverse cracking, rutting (permanent deformation), raveling (loss of aggregate), and potholing. These distress types are interrelated; unchecked surface cracks allow water infiltration, weakening the subgrade and accelerating structural failure (Tjendani & Hastijanti, 2025).

The Surface Distress Index (SDI) is computed incrementally by scoring four distress parameters in a defined sequence: (1) SDI_1 based on crack area percentage; (2) SDI_2 adjusted by crack width category (narrow < 1 mm, medium 1–3 mm, wide > 3 mm); (3) SDI_3 incorporating the number of potholes per segment; and (4) final SDI_4 incorporating rutting depth. The cumulative score determines road condition classification according to Bina Marga standards.

Previous Studies

Several studies have validated the SDI method across Indonesian road networks. Tjendani and Hastijanti (2025) applied SDI on Brigjend. Pol. Imam Bachri Hadi Pranoto Street in Kediri, obtaining a mean SDI of 110 (Light Damage) and recommending rehabilitation with a 70-mm asphalt overlay. Ariawan et al. (2022) evaluated Jalan Raya Buduk in Badung, Bali, finding a mean SDI of 111 (Light Damage) and establishing a strong positive correlation between SDI and IRI ($R^2 = 96.02\%$). Fauji and Kushari (2025) confirmed that SDI is more representative of actual pavement structural condition than smartphone-based IRI, particularly at moderate-to-high distress levels. Akbardin et al. (2026) conducted a multi-index evaluation using PCI, IRI, and SDI on a national highway, finding mean SDI values of approximately 81 across both lanes (Light Damage), recommending a 10-cm asphalt overlay. Jahja et al. (2026) assessed Jalan Molingkapoto Simpang Kwandang using SDI, finding 82% of the road in good condition with cracking as the dominant distress type. These studies collectively confirm that SDI is a robust and field-validated pavement condition indicator for flexible pavement across various road hierarchies and traffic conditions in Indonesia.

METHODOLOGY

Study Location and Scope

The study was conducted on Deandels Road in Probolinggo Regency, East Java Province, Indonesia. The surveyed section spans STA 0+000 to STA 4+500, covering a total length of 4,500 meters of flexible (asphalt concrete) pavement divided into 45 segments of 100 meters each. The road serves as a key regional connector carrying mixed traffic including passenger vehicles, motorcycles, and heavy freight trucks. The survey was conducted in 2026.

Data Collection

Primary data were collected through systematic visual field surveys by trained observers on each 100-meter segment. The following four distress parameters were recorded: (1) Crack Area (%), estimated as the percentage of cracked pavement area relative to total segment surface area using a grid-count method; (2) Crack Width (mm), classified as narrow (< 1 mm), medium (1–3 mm), or wide (> 3 mm) based on direct measurement; (3) Number of Potholes, counted per 100-meter segment; and (4) Rutting Depth (mm), measured using a straightedge placed transversely across the wheel path. Secondary data including unit cost rates for pavement maintenance works were obtained from the 2025 Official Unit Price Analysis (AHSP) issued by the Directorate General of Highways (Circular Letter No. 182/SE/Dk/2025).

SDI Calculation Procedure

The SDI for each segment was computed following the sequential scoring procedure specified in the Bina Marga visual road condition survey guidelines (Survei Kondisi Jalan/SKJ): Step 1 - compute SDI_1 from crack area percentage; Step 2 - adjust SDI_2 by crack width modifier applied to SDI_1 ; Step 3 - compute SDI_3 by adding the pothole score to SDI_2 ; Step 4 - compute final SDI_4 by adding the rutting depth score to SDI_3 . The resulting SDI value was classified according to the Bina Marga classification criteria.

Cost Estimation

Maintenance cost estimation (Rencana Anggaran Biaya/RAB) was conducted for each segment based on its SDI classification and the corresponding maintenance treatment type. Unit prices for AC-WC, AC-BC, AC-Base, aggregate base layer Class A, tack coat, and prime coat were derived from the 2025 AHSP Bina Marga standards. The research flowchart is presented in Figure 1.



Figure 1. Research Flowchart

RESULTS

SDI Calculation and Segment Classification

The SDI was calculated for all 45 segments of the 4,500-meter section. Table 1 presents the SDI classification criteria applied in this study.

Table 1. SDI Classification and Recommended Maintenance Action (Bina Marga Standard)

SDI Value	Condition	Recommended Maintenance Action
< 50	Good	Routine maintenance (crack sealing, minor patching)
50-100	Fair	Periodic maintenance (localized overlay, patching)
100-150	Light Damage	Rehabilitation (structural repair, partial overlay)

> 150	Severe Damage	Reconstruction (full pavement structure replacement)
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Table 2 presents the complete SDI values and corresponding condition classifications for all 45 surveyed segments. Color coding indicates condition severity: white = Good, yellow = Fair, orange = Light Damage, red = Severe Damage.

Table 2. SDI Values and Road Condition Classification - Deandels Road (STA 0+000-4+500)

Station (STA)	SDI Value	Road Condition
0+000 - 0+100	117.5	Light Damage
0+100 - 0+200	117.5	Light Damage
0+200 - 0+300	117.5	Light Damage
0+300 - 0+400	125.0	Light Damage
0+400 - 0+500	87.5	Fair
0+500 - 0+600	25.0	Good
0+600 - 0+700	42.5	Good
0+700 - 0+800	7.5	Good
0+800 - 0+900	20.0	Good
0+900 - 1+000	1.0	Good
1+000 - 1+100	16.0	Good
1+100 - 1+200	42.5	Good
1+200 - 1+300	42.5	Good
1+300 - 1+400	57.5	Fair
1+400 - 1+500	20.0	Good
1+500 - 1+600	20.0	Good
1+600 - 1+700	5.0	Good
1+700 - 1+800	16.0	Good
1+800 - 1+900	25.0	Good
1+900 - 2+000	25.0	Good
2+000 - 2+100	25.0	Good
2+100 - 2+200	25.0	Good
2+200 - 2+300	25.0	Good

2+300 – 2+400	25.0	Good
2+400 – 2+500	35.0	Good
2+500 – 2+600	10.0	Good
2+600 – 2+700	25.0	Good
2+700 – 2+800	25.0	Good
2+800 – 2+900	95.0	Fair
2+900 – 3+000	155.0	Severe Damage
3+000 – 3+100	25.0	Good
3+100 – 3+200	25.0	Good
3+200 – 3+300	16.0	Good
3+300 – 3+400	10.0	Good
3+400 – 3+500	10.0	Good
3+500 – 3+600	25.0	Good
3+600 – 3+700	35.0	Good
3+700 – 3+800	125.0	Light Damage
3+800 – 3+900	45.0	Good
3+900 – 4+000	25.0	Good
4+000 – 4+100	45.0	Good
4+100 – 4+200	25.0	Good
4+200 – 4+300	25.0	Good
4+300 – 4+400	115.0	Fair
4+400 – 4+500	45.0	Good

SDI Value Distribution

Figure 2 illustrates the SDI values per segment in bar chart form, clearly showing spatial variation and critical hotspots along the corridor.

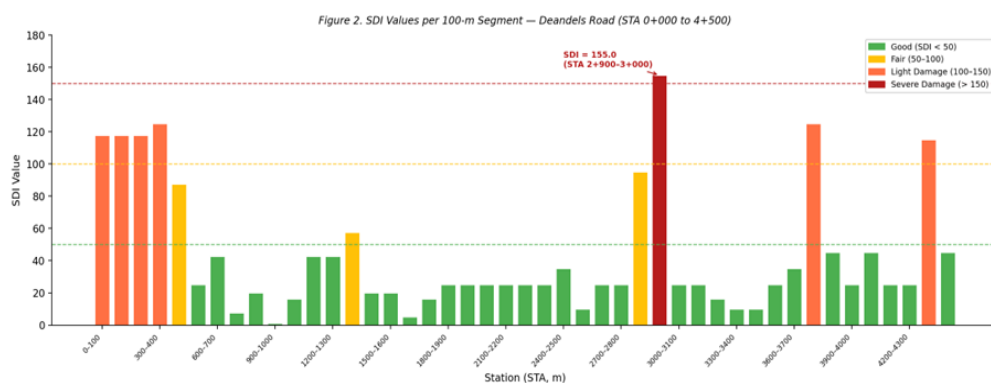


Figure 2. SDI Values per 100-m Segment - Deandels Road (STA 0+000 to 4+500)

The spatial pattern reveals three distinct zones. The initial zone (STA 0+000–0+400) exhibited consistently elevated SDI values ranging from 117.5 to 125.0 (Light Damage), attributable to wide cracking (> 3 mm), extensive crack areas exceeding 10% of surface coverage, and multiple potholes per segment. The middle zone (STA 0+500–2+800) demonstrated markedly improved pavement condition, with the majority of segments classified as Good (SDI 1.0–42.5). The most critical structural failure was identified at STA 2+900–3+000, where the SDI value reached 155 (Severe Damage), reflecting simultaneous occurrence of all four distress parameters at their highest scoring levels: crack area > 10%, wide cracking (> 3 mm), 13 potholes per 100 m, and rutting depth of 40 mm.

DISCUSSION

Overall Condition Distribution

Table 3 summarizes the overall distribution of pavement condition categories across the surveyed section, and Figure 3 presents the distribution as a pie chart.

Table 3. Summary of Pavement Condition Distribution - Deandels Road

Condition	No. of Segments	Length (m)	Proportion (%)
Good	30	3,000	66.7
Fair	4	400	8.9
Light Damage	10	1,000	22.2
Severe Damage	1	100	2.2
Total	45	4,500	100

Figure 3. Distribution of Pavement Condition Categories (45 Segments, Total 4,500 m)

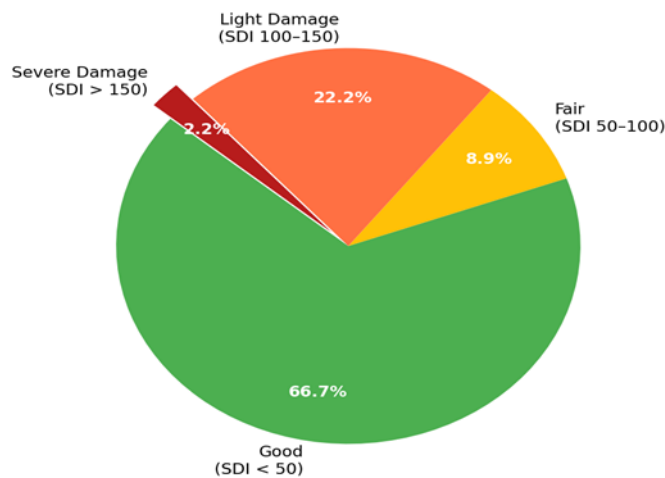


Figure 3. Distribution of Pavement Condition Categories (45 Segments, Total 4,500 m)

The data indicate that 66.7% of the road section retains acceptable structural integrity (Good condition), confirming that the majority of the corridor remains serviceable. However, the combined 22.2% classified as Light Damage and 2.2% as Severe Damage represent segments requiring immediate maintenance attention to prevent progressive structural deterioration, consistent with findings by Tjendani and Hastijanti (2025) and Ariawan et al. (2022) on similar regional roads.

Maintenance Priority Framework and Cost Estimation

Table 4 presents the maintenance program assignments and cost estimates derived from the SDI classification.

Table 4. Maintenance Category, Length, and Estimated Cost

Maintenance Category	Length (m)	Proportion (%)	Estimated Cost (IDR)
Routine Maintenance	3,000	66.7	102,301,162.67
Periodic Maintenance	400	8.9	113,695,918.63
Rehabilitation	1,000	22.2	92,059,387.87
Reconstruction	100	2.2	629,228,173.56
TOTAL	4,500	100	937,284,642.47

The reconstruction program for STA 2+900–3+000 constitutes the largest single cost item, accounting for 67.1% of total estimated expenditure (IDR 629,228,173.56 of IDR 937,284,642.47). This underscores the economic consequence of deferred maintenance: a single 100-meter segment with SDI = 155 requires reconstruction costs nearly equivalent to the combined cost of all other maintenance categories applied to the remaining 4,400 meters. This finding is consistent with the principle of preventive maintenance efficiency reported in national road management literature (Direktorat Jendral Bina Marga, 2025).

The SDI method demonstrated clear utility as a practical pavement condition assessment tool for regional road management. Its entirely visual, non-instrumented approach enabled comprehensive field surveys across the full 4,500-meter corridor without specialized equipment, making it replicable by local road authority personnel with standard training. A limitation of the SDI method is its reliance on subjective visual estimation, which may introduce inter-surveyor variability. Future studies could benefit from integrating SDI surveys with photographic documentation and digital image processing to reduce measurement uncertainty.

CONCLUSIONS AND RECOMMENDATIONS

This study assessed the structural pavement condition of Deandels Road, Probolinggo Regency using the Surface Distress Index (SDI) visual survey method across a 4,500-meter flexible pavement section. The following conclusions are drawn:

1. Of the 45 surveyed segments, 66.7% were classified as Good (SDI < 50), 8.9% Fair (SDI 50–100), 22.2% Light Damage (SDI 100–150), and 2.2% Severe Damage (SDI > 150).
2. The most critical structural failure was identified at STA 2+900–3+000, with an SDI value of 155, requiring full pavement reconstruction.
3. The maintenance priority framework derived from SDI classification yields a total estimated cost of IDR 937,284,642.47, with reconstruction of the critical segment accounting for 67.1% of total expenditure.
4. The SDI visual survey method proved effective as a low-cost, non-instrumented pavement assessment approach directly supporting evidence-based maintenance planning and budget allocation for regional road authorities.

It is recommended that the Public Works Office of Probolinggo Regency prioritize immediate reconstruction of STA 2+900–3+000, implement preventive crack sealing for all Good-condition segments, and adopt the SDI method as a routine monitoring instrument for periodic road condition evaluation. Future research should incorporate International Roughness Index (IRI) measurements alongside SDI surveys to capture both structural and functional pavement performance.

FURTHER STUDY

This study is limited to the visual SDI assessment method and does not capture the functional roughness dimension of pavement performance. Future studies should incorporate IRI data from accelerometer-based smartphone applications such as Roadroid to establish correlation models between SDI and IRI for the Probolinggo road network. Additionally, the integration of GIS-based spatial mapping would enable dynamic visualization of distress distribution across larger road networks, supporting regional pavement asset management systems.

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